Project title: ENHANCEMENT AND DEVELOPMENT OF NUMERICAL MODELS FOR SIMULATING COASTAL SEDIMENT TRANSPORT AND MORPHOLOGY EVOLUTION

Principal Investigator: Dr. Hans Hanson

Contractor: Dept. of Water Resources Engineering
Institute of Technology, U. of Lund
Box 118, Lund, Sweden S-221 00

Contract No: N62558-07-C-0003

Interim Report 2

July 5 – October 12, 2007

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2007**	2. REPORT TYPE	3. DATES COVERED **05-07-2007 to 12-10-2007**

4. TITLE AND SUBTITLE **Enhancement and Development f Numerical Models for Simulating Coastal Sediment Transport and Morphology Evolution**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Water Resources Engineering,Institute of Technology, University of Lund,Box 118,Lund, Sweden S-221 00,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**15**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

ENHANCEMENT AND DEVELOPMENT OF NUMERICAL MODELS FOR SIMULATING COASTAL SEDIMENT TRANSPORT AND MORPHOLOGY EVOLUTION

I. SCIENTIFIC WORK ACCOMPLISHED

1. Background

The GENESIS model has been successfully used in numerous prototype studies involving long-term beach evolution. The model represents longshore subaqueous sand transport processes. However, in many projects, subarial processes such as swash transport and dune erosion plays an important role, not only for the short-term storm erosion but also for the longterm evolution. For this reason, the GENESIS modeling system was further developed to include these processes. The proposed theoretical and modeling approaches were validated against a groin shortening study in Westhampton Beach, Long Island, NY.

Westhampton is located on the eastern south shore of Long Island, between Shinnecock Inlet and Moriches Inlet (Fig. 1). In December 1992, 22 years after Groins 12-15 were constructed, a northeaster opened two inlets (called Pikes Inlet and Little Pikes Inlet) directly west of the groin field. Pikes Inlet, located most westward, gradually shoaled and was readily closed manually (Bocamazo and Grosskopf 1999), but Little Pikes Inlet enlarged in the eroding down-drift area directly west of Groin 15 (Fig. 2). In November 1993, NAN closed the breach by hydraulic fill placement (Bocamazo and Grosskopf 1999). In 1996-1997, a tapered groin transition to the west was created by shortening Groins 14 and 15 and adding a short groin (called Groin 14A) between them. Groins 14 and 15, originally 480 ft in length were shortened to 417 ft. Groin 14A, constructed between Groins 14 and 15 in 1997, is 337 ft long. Groins 1-13 are 480 ft long. Groins 1-13 have not been maintained, and possible shortening would offer the opportunity of refurbishing these groins as needed.

The tapering included placement of fill in the existing groin compartments and beach. The dune and berm west of the groin field were also restored as part of the Westhampton Interim Project (Bocamazo and Grosskopf 1999). The groin tapering and beach fill have been successful, and the planned renourishment of 3 years is being extended to 4 years. The renourishment plan has provision for fill in groin compartments 7 through 15, as needed, to promote littoral drift.

2. Objectives

As an alternative to the existing condition, NAN has proposed modification of the Westhampton groin field by shortening of groins in the eastern and middle portions of the groin field, tapering of groins on the western end of the groin field, and continued renourishment. Groin shortening may offer a cost-effective solution, as compared to beach nourishment from an external source, for maintenance of the beach west of the groin field for a certain length of time until the beach and dune in the groin compartments return to equilibrium with the modified structures. In this study, a uniform reduction in length of 100 ft of Groins 1-13 was made, and Groin 14 was

reduced by 27 ft to achieve a length comparable to Groins 1-13. This shortening of the groins was considered compatible with estimates to be given with a new and substantially complex predictive technology developed for this study.

3. Procedure

Kraus et al. (1994) demonstrated that the GENESIS shoreline response model quantitatively accounted for gradual infilling of groin compartments from east to west (Nersesian et al. 1992) and the bypassing among them. Each groin compartment has potential of retaining some sand as it enters the compartment, as well as bypassing material down drift. In addition, reversals in longshore transport direction are represented in GENESIS.

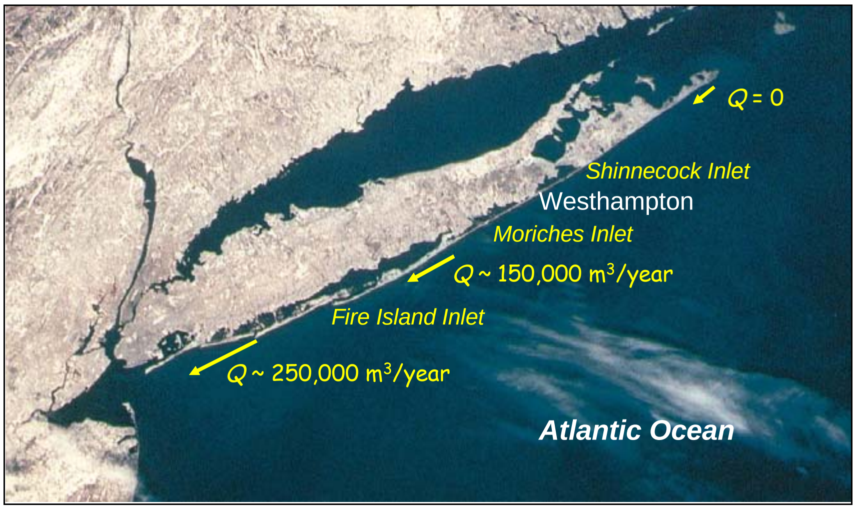

Figure 1. Study site location map.

Technical elements to be considered are appropriate representation of the groin shortening, release of correct volume of sand to the littoral zone from the berm and dunes within the context of shoreline response modeling, time delays caused by capture of a certain amount of sand in down-drift groin compartments, response of the regional up-drift and down-drift beaches, and randomness in wave climate that can cause seasonal and annual reversals in longshore sand transport. Simulations for on the order of 20 years are necessary. In a design study, ensembles of tidal phasing and sequence of storms must be made to obtain a range of probable results, but this type of effort was beyond the scope of development of physical processes understanding and initial analytical implementation done here.

Figure 2. Little Pikes Inlet, May 1993, with Groins 15 and 14 from left to right, respectively, on right side of photograph.

In the present study, a research version of GENESIS was modified to represent the dune as a source of sand that, once eroded, will move the local shoreline seaward. Dune erosion is calculated through a wave-impact model (Larson et al. 2004), indicating that the dunes are only accessed for potential erosion during times of high water level and storms. The dune growth process is represented through landward transport by wind-blown sand (WBS).

Gradients in longshore sand transport rates will adjust the shoreline through redistribution of sand alongshore that is released from the dunes to the beach profile. This procedure is consistent with long-term response modeling approach as is described by shoreline response models.

4. Modification of Genesis to Represent Dune Erosion and Growth

4.1 Dune Erosion and Recovery Processes

The interaction between the beach and the dune behind it is mainly controlled by two natural processes: (1) erosion of the dunes caused by the impact of waves reaching up to the dune foot, and (2) WBS transport from the dry beach berm to the dunes. If wind speed exceeds a threshold for sand movement, and if the beach is not wet or frozen, WBS transport can occur. Sand blown from the dry beach berm will move into the dunes. Although likely having a seasonal signal, dune growth by WBS transport was assumed to be constant over time and depend on a term proportional to the wind forcing, the beach berm width, and a shape function expressing the transport distribution across the berm. As the beach berm becomes wider, e.g., due to accretion of the beach up drift of a groin, the wind blowing across the berm will supply more sand to the dunes, and they will advance seaward with the accreting shoreline, although with some delay.

Dune erosion by wave impact was treated more rigorously because available data allowed this. Based on data on water level and simultaneous wave conditions, the total wave run-up level was calculated. Besides the wave conditions, the wave run-up level depends on the width of the beach berm between the shoreline and the dune foot. An

empirical coefficient was defined to set the magnitude of the erosion rate. If the run-up level exceeded the dune foot elevation, the eroded volume of sand from the dune was calculated. As the beach berm becomes narrower, i.e., due to erosion down-drift of a groin, more waves will reach the dune foot, and the dune will recede with the shoreline, again with some time lag.

In the modified GENESIS, material eroded from the dune during a storm is distributed across the beach profile in the particular calculation cell from the top of the berm to the depth of active movement. Therefore, the volume released is distributed from the berm elevation of 9.5 ft to the depth of closure of 26 ft. Vertical measures (water level, wave run-up, dune foot elevation, and dune height) were assumed to be uniform alongshore and represented by their alongshore average values. Water level and wave run-up were updated every 3 hr. This is consistent with the 1-line concept upon which the GENESIS model is based. All horizontal measures (shoreline and dune foot location), on the other hand, are allowed to vary alongshore and are recalculated every 3 hr.

The magnitude of the transport coefficients for dune erosion due to waves and recovery due to WBS transport were determined provisionally as a part of the GENESIS calibration. Digitized aerial photographs of the area gave an average dune foot migration (advance) rate within the groin field from 1994 to 2004 of 7 ft/year. With an average dune height of 5 ft above the berm, this seaward translation corresponds to about 0.8 cy/ft/year, which is considered to be a representative value for the area. However, this value represents the net effect on the dunes of wave impact erosion and dune growth by WBS, where the relative magnitude of the two components is not known. In this application, it was provisionally assumed that the WBS accumulation amounts to 1cy/ft/year and the wave impact erosion accounts for 0.2 cy/ft/year.

In the calculations, the dunes and the beach (consisting of the berm and the underwater profile), respectively, are considered as two communicating morphologic bodies. Sand that is eroded from the dunes is supplied to the beach seaward of in the GENESIS cell, and all WBS transport to the dune is supplied from the same beach cell. Sand is transported along the beach as usual by gradients in longshore sand transport, but not along the dunes (dunes do not change by longshore gradients in transport).

4.2 Expected Effect of Groin Shortening

If the beach is in equilibrium with the groin field, a reduction in groin length while preserving basic cross section is intuitively expected to lead to recession of the shoreline and dune after the beach has reached a new equilibrium. The time scale involved depends on the storm frequency. By shortening the down-drift groins, more sand can be transported out of the groin field, which would lead to a decreased volume of sand in the field. By shortening the up-drift groins, however, the trend would be opposite. More sand will enter the down-drift groin compartments and fill them, gradually moving from compartment to compartment until reaching the down-drift beach to the west of the groins.

Erosion of the dune during storms also enters this process. Both wave impact erosion and WBS recovery are sensitive to beach width. A narrower beach berm increases the run-up elevation, leading to more dune erosion. At the same time, a narrow beach berm reduces the recovery rate by WBS transport. Both of these mechanisms promote

an increased tendency for the dune to move landward with the shoreline. As the dunes recede landward, however, they will supply more sand to the beach berm, thus reducing recession of the shoreline.

In conclusion, the dune and berm (as represented by shoreline position) are expected to recede if the groins are shortened through calculation with the modified GENESIS. The time scale of this process is not known a priori and is an output of the model.

5. Simulation of Shoreline Response to Groin Shortening

Sensitivity tests are first presented that show the revised GENESIS producing results that are in agreement with qualitatively intuited behavior of the shoreline in response to groin shortening. Then, simulations are made for shortening the groins at Westhampton Beach.

5.1 Sensitivity Tests

1-D Schematic Cases – Cross-Shore Processes Only. The first set of runs was made to investigate the balance between the wind, which transports sand from the beach to the dunes, and the wave impact, which removes sand from the dunes and transports it seaward and along the profile.

An initially straight shoreline is exposed to waves. The active beach profile starts at the depth of closure at -26 ft up to the berm height at +10 ft NGVD. The dune has an average height of 5 ft above the berm. The initial berm width (horizontal distance from the shoreline to the foot of the dune) is set to 260 ft, based on preliminary GIS analysis. Because the waves are uniform alongshore, the longshore sand transport rate is constant alongshore and, thus, causes no changes. Hence, all change is caused by the exchange of sand between the beach and the dune.

Most of the time, the waves will not reach the dune foot. During this time, sand is transported by the wind from the beach to the dune, causing the beach to gradually erode and the dune to accrete. Only occasionally, wave run-up (including the water level) will reach above the dune-foot elevation. Then, more pronounced dune erosion and an associated beach accretion occur.

To investigate the coupling between the beach and dunes, this sensitivity test was run for 30 years, using the wave climate at Westhampton (Fig. 3). In the original configuration, the shoreline (green line in Fig. 3) was initially 1,180 ft from the baseline, and the dune foot (blue line) was initially located 920 ft from the same baseline, resulting in an initial berm width of 260 ft. The system is in long-term equilibrium (no long-term trend) where the shoreline fluctuations are small. Similarly, the dune foot location shows no long-term trend. However, it varies more because the beach profile height (26 + 10 ft) is about seven times larger than the dune height (5 ft). Thus, when the beach and dune exchange material, the same volume causes more change in dune foot location than it does in shoreline change.

In a second configuration, the shoreline (black line) was set back 100 ft, compared to the initial condition in the first configuration, while leaving the initial dune foot location the same as in the first configuration. The dune (red line) displays similar short-term fluctuations as in the first configurations, but over the years it is gradually receding a bit more and recovers a bit less, compared to the first configuration, to find its equilibrium position further landward. The difference between the dune foot locations of the two configurations is indicated by the purple line in Figure 3. Initially the difference is zero but gradually increasing over the years. After some 22 years, the

difference has grown to 87 ft after which it remains virtually constant. Over the same time, the difference in shoreline location (cyan line) has decreased from its original 100 ft to the same 87 ft as for the dune. Thus, the beach and dune are now re-established in dynamic equilibrium where the beach and dune have the same relative locations as before the set-back of the shoreline.

These test cases show that there is a long-term dynamic equilibrium balance between the beach and the dune behind it. If the beach is moved away from its original equilibrium location, the beach and dune will change accordingly to re-establish a new dynamic equilibrium.

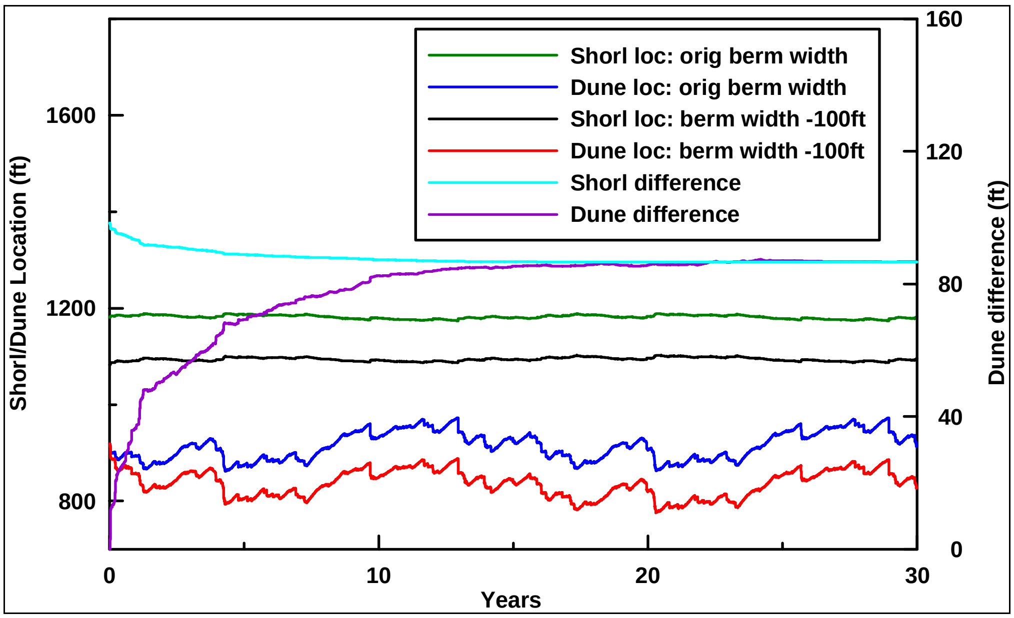

Figure 3. Temporal evolution of shoreline and dune foot location for the two 1-D cases. In the first case (green shoreline & blue dune foot), the features show no long-term trend. In the second case (black shoreline & red dune foot), the shoreline is set back 100 ft. Gradually, the dune foot receded the same distance.

Schematic cases – Combined Cross-shore and Longshore Processes. To investigate the influence of longshore processes on the dynamic beach and dune, a second set of schematic cases was studied. The first configuration involves a 43,000 ft long shoreline (Fig. 4) with an initial shoreline (green line) which is selected to be 'close-to-equilibrium' in plan shape. Four groins are located at the center of the shoreline stretch at a distance of 1,300 ft from each other. The total length of each groin is 1,050 ft, and the shoreline position within the groin field is initially at 920 ft. Thus, the groins initially penetrate some 130 ft into the Atlantic Ocean. The initial dune foot is located 130 ft beyond the shoreline. Four groins define three compartments, and with this configuration predictions of sand bypassing can be examined.

The beach is exposed to schematized waves for 40 years. The wave climate consists of two sets of waves alternately acting. The first set has H_{os} = 3.9 ft, T_s = 4 sec, and direction = 15 deg relative to shore normal. The second set has H_{os} = 10 ft, T_s = 8 sec, and direction = 15 deg relative to shore normal. The first set of waves lasts for 6 weeks and does not reach the dune foot, i.e., during this period the dunes can grow by

WBS transport. The second set lasts for one week and reaches up to the dune foot causing dune erosion. The calculated shoreline evolution over the 40 years (Fig. 4) shows that the accumulation on the up-drift side of the groin field and in the first (left) groin compartment continues, whereas the beach is eroding in the other two groin compartments as well as down-drift of the groin field. However, the change becomes gradually smaller over time, and the shoreline approaches an equilibrium plan shape. The mean net longshore sand transport rate was close to 200,000 cy/year.

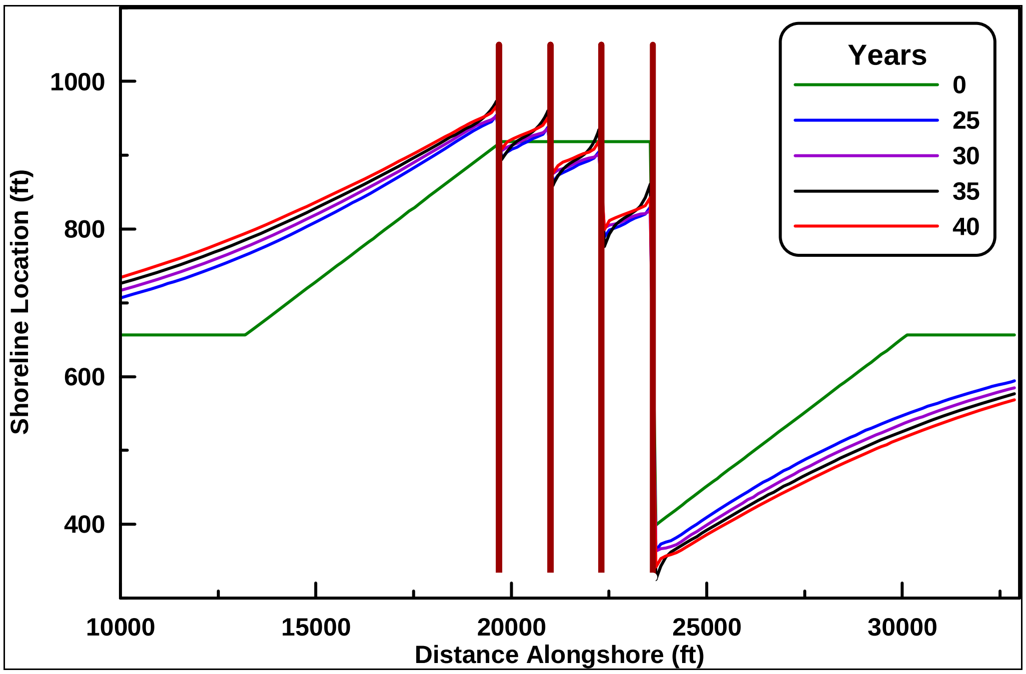

Figure 4. Plan form evolution of 2-D schematic Case 1 – a beach with longer groin field at the mid-section.

Figure 5 shows the temporal evolution of shoreline position at the center of the groin field (red line). Initially, the outflow of sand from the mid groin compartment is greater than the inflow, and, as a result, the shoreline recedes. Gradually, as the shoreline on the up-drift side of the up-drift groin moves closer to the groin tip, the influx of sand increases. Similarly, as the shoreline on the up-drift side of the down-drift groin moves landward and away from the groin tip, the outflow of sand decreases. Thus, the net outflow of sand from the groin compartment slowly decreases and, after some 10 years, is replaced by a net influx.

The dune foot (blue line) is initially 130 ft landward of the shoreline. This berm width is apparently larger than its equilibrium value. As a result, the dune foot initially migrates towards the shoreline, and the berm width (black line) is reduced from its original width to about 55 ft after some 10 years. This reduction in berm width indicates that the beach is moving towards an equilibrium state and that the shoreline recession is slightly too rapid for the dune foot to keep up. As the shoreline starts to advance, and at a slower pace than the erosion, the berm width recovers slightly and remains more or less at a constant value over the final two decades of the simulation period. This is a strong indication that the beach has reached a dynamic equilibrium state. As in the previous case, the location of the dune varies much more than that of the shoreline.

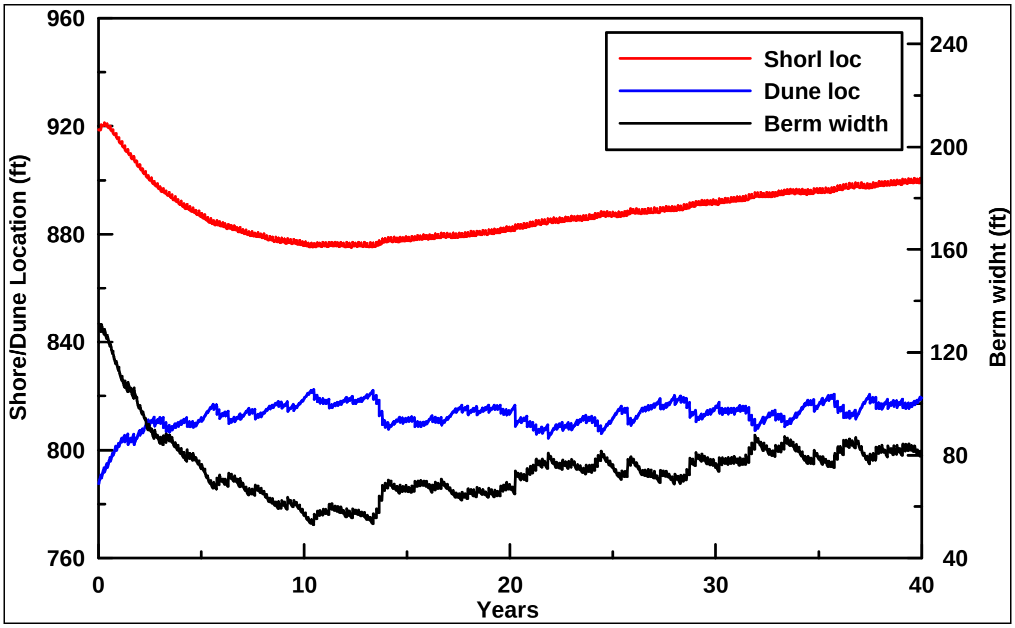

Figure 5. Temporal evolution of shoreline and dune foot locations and berm width for 2-D schematic Case 1.

From Figure 6, it is observed that the shoreline and dune foot, which are in parallel at the beginning of the simulation, remain parallel at the end. This is because the wave climate is uniform alongshore. With waves varying along the shore, the equilibrium berm width would also vary alongshore.

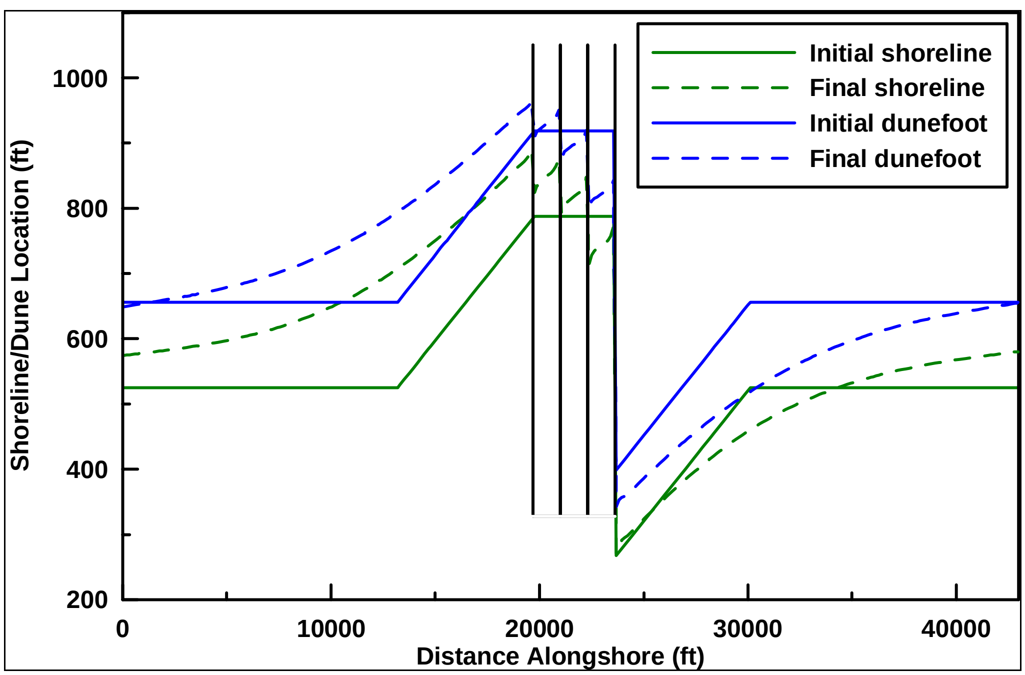

Figure 6. Initial and final plan forms of shoreline and dune foot for 2-D schematic Case 1.

In the second stage of this sensitivity testing, the final result of Case 1 served as the initial condition for a consecutive Case 2 in which the lengths of the four groins were reduced by 100 ft. Because Case 1 was run to equilibrium, it is now be possible to see the isolated effect of groin length reduction as we run Case 2 configuration for another 40 years. Hopefully, the beach will develop into a new dynamic equilibrium stage.

Figure 7 shows the evolution of the beach plan form in Case 2 over 40 years. The initial condition corresponds to a plan form in equilibrium with the longer groins. With the shorter groins, the shoreline moves back some 65 ft near and inside the groin field, i.e., for about 67% of the groin length reduction.

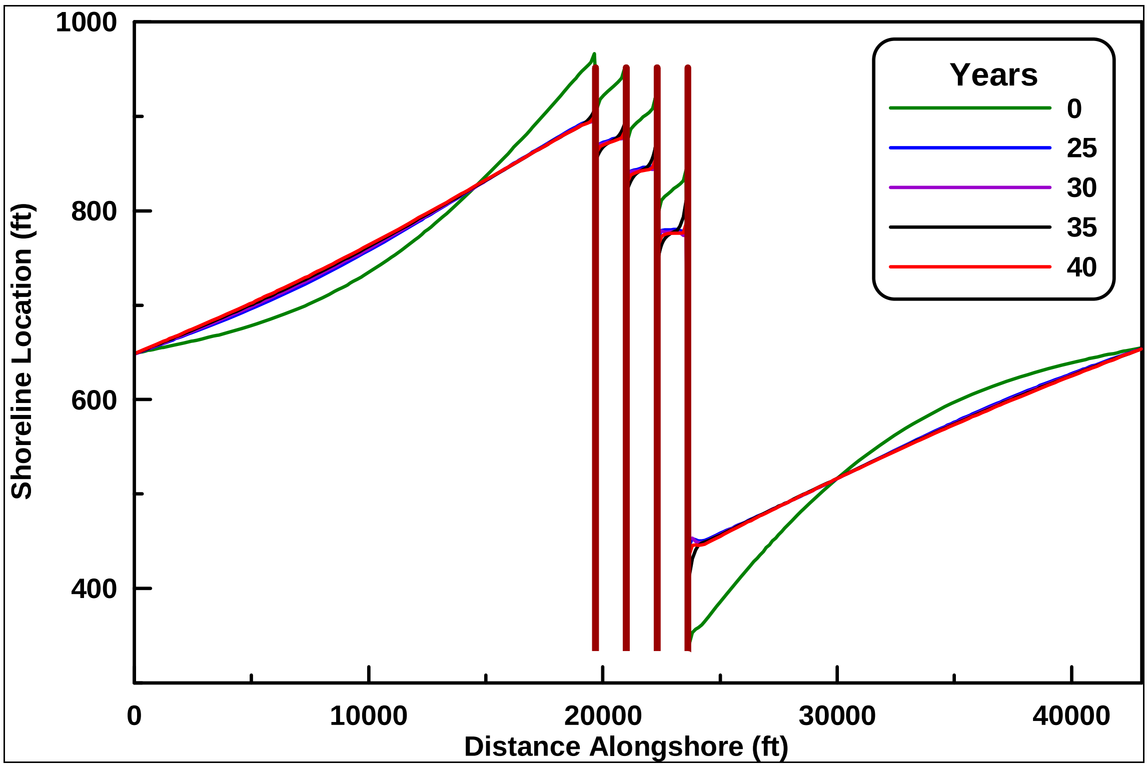

Figure 7. Plan form evolution of 2-D schematic Case 2 – a beach with shorter groin field at the mid-section.

Temporal evolution of the shoreline and dune foot location, as well as that of the berm width, show the expected behavior (Figure 8). The shoreline recedes at a gradually decreasing rate, and at the end of the simulation, this recession is only marginal. Thus, for the shoreline to recede a distance equal to the groin length reduction of 100 ft, it probably several more decades will be required (or an unusual sequence of severe storms).

In summary, two sensitivity tests have verified the concept that shortening of the groins will result in a recession of the beach and dune. However, for the recession distance to equal the reduction in groin length, several decades will be required or an

unusual sequence of strong storms over the years. The application has relevance to the situation at Westhampton Beach because the beach and dune transport parameters, the net longshore transport rate, and groin dimensions entering these tests were similar to those at Westhampton Beach.

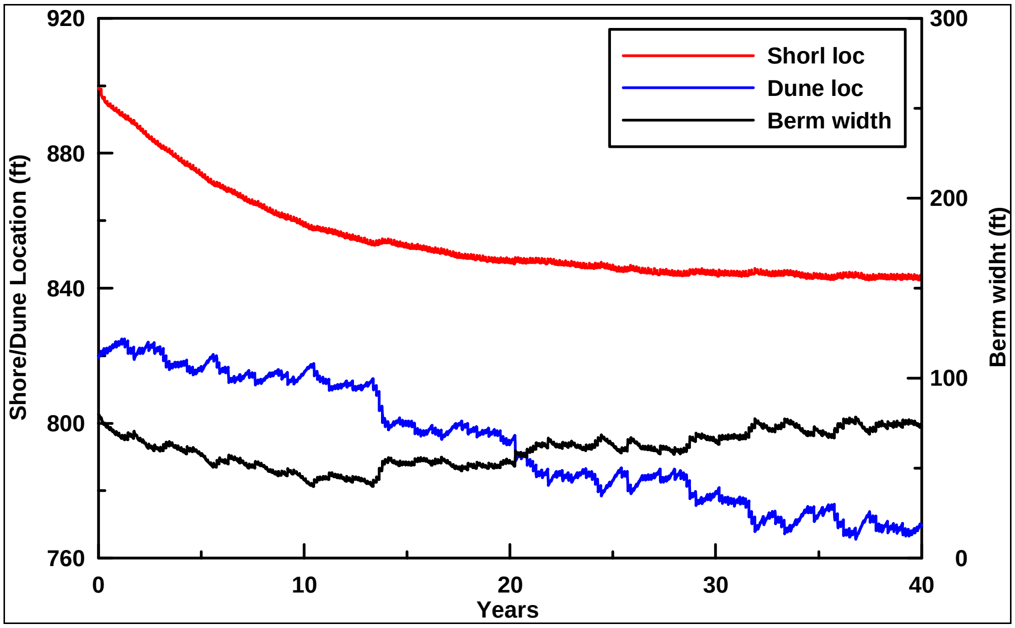

Figure 8. Temporal evolution of shoreline and dune foot locations and berm width for 2-D schematic Case 2.

5.2 Westhampton Beach Simulations

Calibration. With confidence in the formulated concept regarding the interaction between the beach and the dune behind it gained from the sensitivity tests, the situation at Westhampton Beach was simulated. The transport parameters in GENESIS were set to match the net longshore transport rate at the site, taken to be about 200,000 cy/year directed to the east. Similarly, the coefficients for the transport to and from the dune were set based on the experience from the cross-shore tests as described in the previous section. Simultaneous wave and water level data (from the Sand Hook tide station) were input to the modified GENESIS to calculate long-time dune and beach berm change. WIS wave information was available from 1 January 1976 to 31 December 1995 and water level data (including storm surges) were available from 1 January 1980 to 31 December 2000, both at 3-hr intervals. Thus, the period with simultaneous waves and water levels covers 1 January 1980 to 31 December 1995. These data served in the calibration process where the two measured shoreline positions of 1988 and 1995 were included. The result of the calibration, called WH1, is shown in Figure 9.

Starting with the measured 1988 shoreline (green line), the main features of the measured 1995 shoreline (red line) were reproduced (blue line). In particular, the continued accretion on the up-drift side of the groin field is replicated, as well as the small changes in the western groin compartments and the pronounced accretion in the groin compartments near the center of the groin field. Along other sections the

agreement is not as good. In particular, the model over-predicts the down-drift erosion to east of the groin field. The mean calculated transport rate alongshore, agrees well with prototype estimates and was close to 200,000 cy/year. The groin lengths indicated by 'Length 1995' in Table 1 were entered in the calibration simulations. Overall, the calibration is judged to be satisfactory.

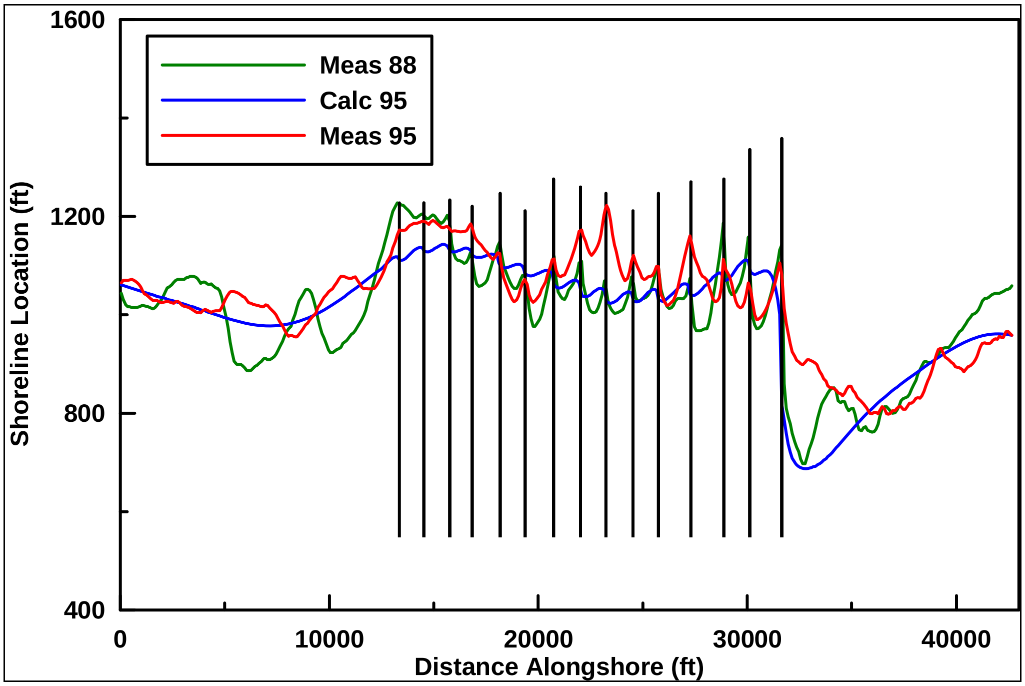

Figure 9. Case WH1 - calibration run for Westhampton Beach. Simulation from 1988 to 1995.

Response to Groin Shortening. To quantify the response of the dune and beach to groin shortening, GENESIS was run for 30 years for two groin lengths, referred to as WH2 and WH3, respectively. In WH2, the simulation started with the measured 1995 shoreline and the beach fills that were reported to be added in 1996-1997. During initial construction in 1996 and 1997, about 3.5 Mcy of sand dredged from an offshore borrow site was placed from Groin 7 to approximately 10,000 ft down drift (west) of Groin 15. For the modeling, the fill was split with 1.5 Mcy within the groin field and 2 Mcy distributed to the west of Groin 15. The beach section consisted of a +9.5 ft berm, about 90 ft wide.

Figure 10 shows the result of the 30-year WH2 simulation with the existing groins (indicated as "Length 1997" in Table 1). As expected, accumulation continues up drift of the groin field and also somewhat inside the western of the groin field. Erosion occurs in the last groin compartment and, of course, down drift of the groins.

Table 1. Groin lengths at Westhampton Beach (ft)			
Groin No.	Length 1995	Length 1997	Shortened Groins
1	480	480	380
2	480	480	380
3	480	480	380
4	480	480	380
5	480	480	380
6	480	480	380
7	480	480	380
8	480	480	380
9	480	480	380
10	480	480	380
11	480	480	380
12	480	480	380
13	480	480	380
14	480	417	380
14b	-	417	380
15	480	337	337

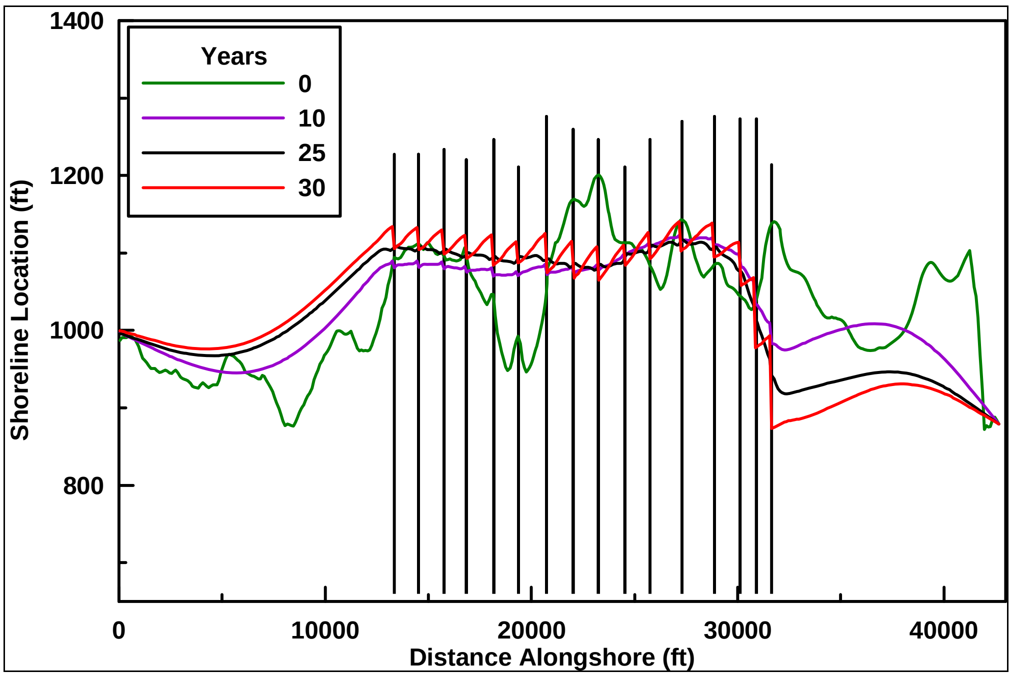

Figure 10. Calculated shoreline change at Westhampton Beach over 30 years with existing groins.

GENESIS was run for the same waves and water level, but with the groin lengths reduced as indicated by "Shortened Groins" in Table 1 for WH3. The result of this simulation is shown in Figure 11. Compared to the results for the original groin lengths (Figure 10), there is a notable difference. Shoreline advance (accretion) up drift of the groin field and inside the western side of the groin field was substantially

reduced. Likewise, the significant recession in the easternmost groin compartment and down drift of the groin field was also substantially reduced.

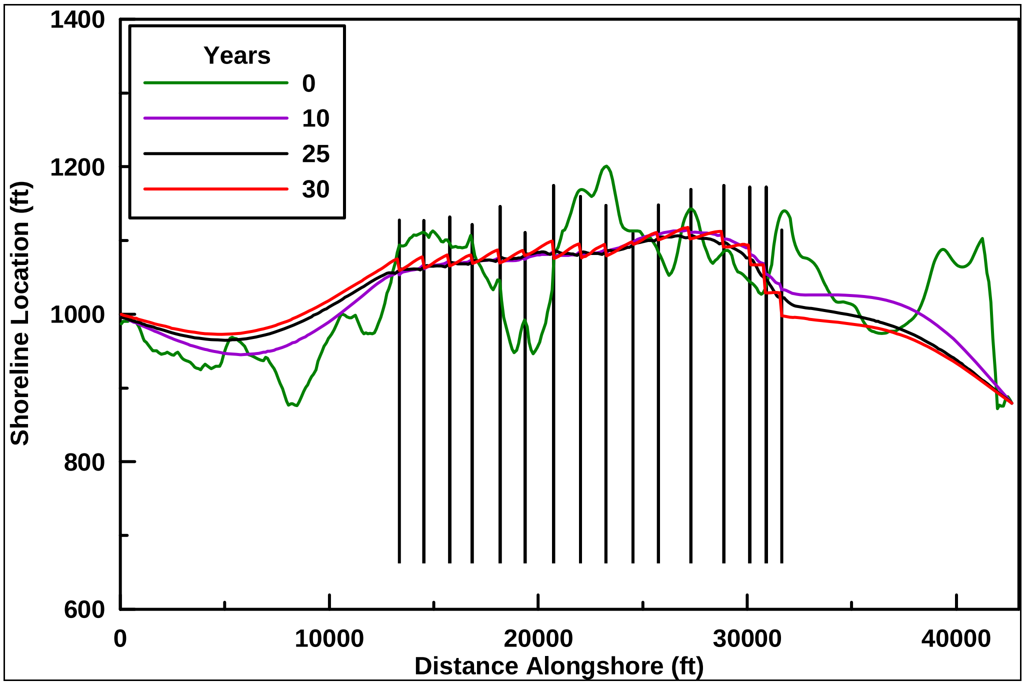

Figure 11. Calculated shoreline change at Westhampton Beach over 30 years with shortened groins.

If the simulation after 30 years using the 1997 groin lengths is compared to that for the shortened groins, up drift of the groin field the shortened groins trap 330,000 cy less that the original groins (Figure 12) and inside the groin field they trap 350,000 cy less. At the same time, there is 780,000 cy more sand down drift of the groin field with the shorter groins, corresponding to four times the annual net transport rate. If the entire beach and dune inside the groin field (from Groin 1 to Groin 15) follow the length reduction completely and, thus, recede the full 100 ft the released volume would amount to about 2.8 Mcy. Thus, the released 780,000 cy is only about one-third of the total potential of 2.8 Mcy that can be released over the subaerial and sub-aqueous beach.

This section shows that the beach and dune at Westhampton Beach will recede up drift and inside the groin field and that the down-drift beach will accrete in response to shortening of the groins. However, it will take several decades before the down-drift beach will receive the full benefit of the groin length reduction and to establish a new equilibrium.

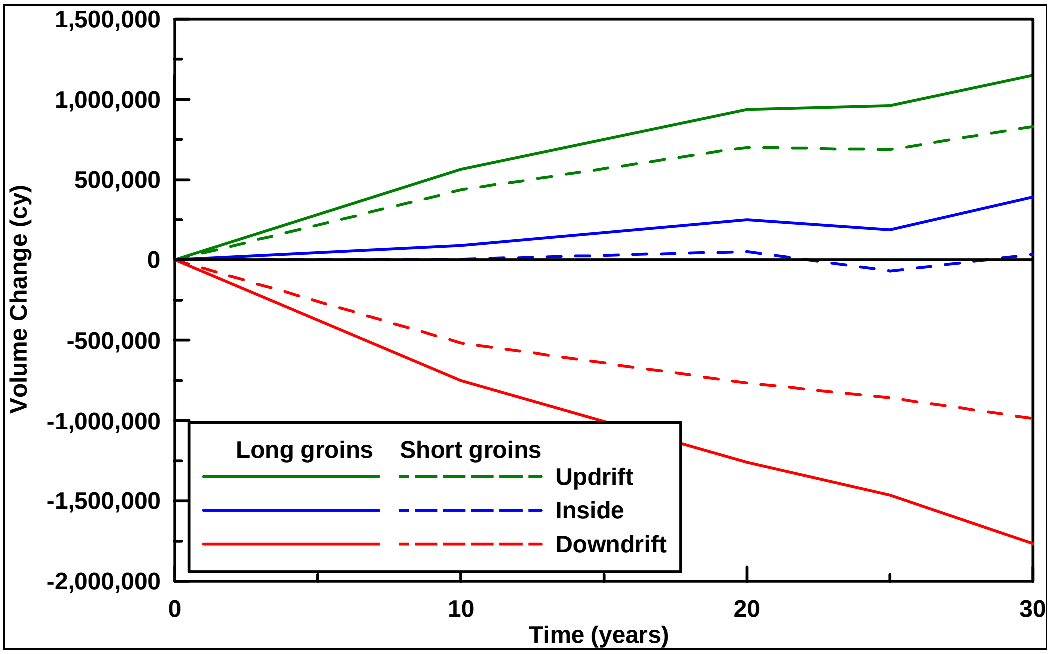

Figure 12. Volumetric evolution up-drift, inside, and down-drift the groin field for situations with long and short groins, respectively.

II: SIGNIFICANT ADMINISTRATIVE ACTIONS AND OTHER INFORMATION

No significant administrative actions were taken.

III: FUNDS REMAINING AND LIST OF PROPERTY ACQUIRED

The total contract is for $570,000. Payment upon receipt of these reports is scheduled at $50,000. Therefore, the amount of funds remaining under contract at the end of this report period is $470,000.

REFERENCES

Bocamazo, L.M., and Grosskopf, W.G. 1999. Shore response to groins, Westhampton, New York. *Proceedings Coastal Sands '99*, ASCE, 2,073-2,089.

Kraus, N.C., Hanson, H., and Blomgren, S. 1994. Modern functional design of groins. *Proceedings 24th Coastal Engineering Conference*, ASCE, 1,327-1,342.

Larson, M., Erikson, L., and Hanson, H. 2004. An analytical model to predict dune erosion due to wave impact. *Coastal Engineering* 51: 675-696.

Nersesian, G.K., Kraus, N.C., and Carson, F.C. 1992. Functioning of groins at Westhampton Beach, Long Island, New York. *Proceedings 23rd Coastal Engineering Conf*erence, ASCE, 3,357-3,370.